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ABSTRACT

Power Distribution system constitutes the link between electricity utilities and consumers. This system, therefore represents the face of the utility. To meet the growing and changing system load demands, proper power distribution planning needs to be done by the utilities. Use of Geographical Information System (GIS) will facilitate proper planning and analysis for power distribution networks. Geographical Information System (GIS) technology plays an important role in mapping the HT/ LT consumers and electrical network assets, on a geographical base map, to help define the consumer's electrical connectivity. The aim of the research would be to integrate data using GIS to plan and analyze a distribution network for system optimization .

Keywords: Distribution System, GIS, Networks, Mapping, Optimization

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1. Introduction

The Indian Power Sector has grown in capacity and size over the years, the installed generation capacity having increased from 1,363 MW in 1947 to 1,60,000 MW as on 31.3.2010. The progress has been impressive in terms of generation but the distribution sector has been facing severe losses, with Aggregate Technical and Commercial loss reaching to an average of 33 %.

Distribution is considered as the weakest link in the power sector due the large energy losses occurring at the distribution end. The distribution losses in India's power sector occur on both sides of the energy meter – the utility side as well as the consumer side High technical losses in the system are primarily due to inadequate investments over the years for system improvement works, which has resulted in unplanned extensions of the distribution lines, overloading of the system elements like transformers and conductors, and lack of adequate reactive power support. At the consumer end, the problems leading to avoidable energy and revenue losses are lack of meters, prevalence of flat rate tariffs over metered tariffs, non-payment, theft, illegal connections, a lack of consumer education in the rural sector, rampant political interference, and inefficient electricity use.

Therefore there is an acute need for a constant and long lasting solution aimed at improving and strengthening the Power Distribution network with minimum losses through integrated planning for the System. It is not only enough to analyse how a particular portion of the network may be modified to improve its performance today, but also determining what would be the optimal solution when allowance has also to be made for the uncertainties in the prediction of the future scenario of customer demand.

Since the distribution network of a power utility has a geographical reference, it can be beneficial to create the network on the computer in a geographical context using GIS as a tool. This will provide useful reference for setting up of new facilities, provide necessary information on land use pattern for planning optimum expansion of network and enable more systematic network operation and maintenance.

The thing that distinguishes an electrical utility information system from another information system – such as those used in banking or payroll systems is need to record geographical information in the database. Electrical utility companies need two types of information, which are details on the location of facilitates, and information on the spatial interrelations between them. The integration of geographically referenced database, analytical tools and in – house developed electrical analysis software tools will allow the system in improving inventory control, preventive maintenance and overall system performance.

Network tracing can be carried out using the information on network connectivity and component characteristics that are already stored in database. On this, several network tracing functions such as path optimization, range finding, path finding, etc, can be performed. GIS can be used as an effective tool to help the engineers in the design of electricity distribution systems

2. Literature Review

The study of the existing literature involved the study of the power sector focusing on GIS based Distribution System Planning and Analysis. Papers related to the topic have been studied.

Skok, 2002 [1] In order to enhance the serviceability in the distribution system genetic algorithm and GIS based method is proposed in this article for planning the link distribution networks. All practical issues such as cost parameters (investments, line losses, maintenance), and technical constraints (voltage drop, thermal limit, reliability) as well as physical routing constraints (obstacles, high cost passages, existing line sections) are taken into consideration. Fuzzy set concept and scenario representation (tree of futures) to model uncertainties, as well as decision making guided by a paradigm of multi-criteria risk analysis are discussed. The merits of the approach are discussed by analyzing its application to a study case based on a real case in a Croatian utility.

The ability to supply consumers of an urban area without any longer interruption during a feeder or substation transformer outage is assured by the link network configuration. Genetic algorithm based method has been proposed in this article as a useful technique for computing near-optimal solutions based upon many practical issues not only in an economic sense but also in a sense of technical criteria and physical routing constraints are taken into consideration. Fuzzy set concepts to model uncertainties and decision making guided by a paradigm of multi-criteria risk analysis provides the experienced planner with a set of acceptable solutions in terms of different (mainly converse) planning criteria taking into account different future scenarios. However, the authors recognize that presented methodology must grow with respect to the issues like independent investments in electricity supply, deregulated distributed generation and other energy sectors planning.

Dr. Nagesh Rajopadhyay, 2002 [2] In this paper a GIS Solution for preventing pilferage has been presented. The proposed methodology is tested on SmallWorld GIS software. Some of the conclusions drawn are:
A GIS System integrated with Consumer billing system can be effectively used in detecting the power pilferage
Pilferage detection can be done at consumer, distribution transformer and feeder or substation levels.

Analysis of patterns of individual consumption over GIS can help in identifying the sources of pilferage at subscriber level.

Ruijin, 2002 [3] The geographic information systems (GIS) platform is used in spatial load forecasting (SLF) and the mathematical models of the substation location and capacity optimisation problems are established in this paper. Based on the theory of network flow, a new multi-period optimal selecting algorithm of substation is proposed, which could determine the reasonable location, capacity and time that are put into the running of the substation. The real instance shows that this algorithm could solve the multi period optimal selecting problem of substations in distribution system planning (DSP) successfully, and has a practical value.

This paper has entirely described the distribution system SLF and the optimal planning of substation location and capacity. The method of the distribution system SLF is brought forward based upon GIS platform. This method can provide the forecasting the load increment of the space, of the time and of the quantity in the distribution system. On this condition, based on the theory of network flow, a new multi-period optimal selecting algorithm of substation is proposed, which could determine the reasonable location, capacity and time that put into running of the substation. The result indicates that this method could preferably meet the need of distribution system planning.

Boulaxis, 2002 [4] Optimal feeder routing is an important part of the general optimal distribution network planning. This paper proposes a new algorithm for the optimal feeder routing problem using the dynamic programming technique and geographical information systems (GIS) facilities. All practical issues, such as cost parameters (investments, line losses, reliability) and technical constraints (voltage drop and thermal limits), as well as physical routing constraints (obstacles, high-cost passages, existing line sections) are taken into consideration. The algorithm developed is validated comparing its results for a simplified study case, with those obtained by an established solver. The effectiveness of the algorithm is further illustrated for a "real-world" study case.

The optimal routing of distribution networks was addressed in this paper, using a dynamic programming technique and GIS facilities. The advantage of the developed algorithm is that the total cost (investment, transmission losses and reliability) for a multiyear study period is optimized, taking into account all constraints, technical (voltage drop, thermal limits) and physical (obstacles, high cost passages, etc.), as well as existing line sections. Dispersed generation can be also taken into account. Consequently, the developed algorithm can be effectively applied in realistic problems, where all the above mentioned factors exist. In addition, it could be incorporated in a general optimum planning distribution network software.

Glamocanin, 2003[5] The reduction of customer interruption due to failures in the distribution network is one of the leading priorities of power companies, which are working in market driven environment. The faults in the distribution network determine the distribution system reliability level and service quality, and they are the source of complains and customers' dissatisfaction. The reduction of customer interruption is of a significant importance for extremely loaded distribution systems. On the other hand, the utilization of full capacity of the lines and transformers is the common challenge in the operation of distribution system in a market environment. How to reduce the service interruption duration and customer outage costs when a failure occurs in the medium voltage network will be presented in this paper. By using the geographic information system (GIS) and distribution state estimation (DLE) the dispatcher is enabled to make a decision how to proceed with switching operation to redistribute the load of the customers that are in the fault area to the neighboring feeders.

In the de-regulated electricity the power trading companies are faced with new problems. The biggest challenge is caused by the uncertainty in the load magnitudes. In order to minimize the risk in power purchase and also in retail sales, the power traders should have as reliable and accurate estimates for hourly demands of their customers as possible. New tools have been developed for the distribution load estimation of the trading companies. These tools are based on the flexible combination of the information available from several sources, like load measurements, load models, statistical data in combination with GIs. By using the Geographic Information System (GIS) and Distribution State Estimation (DLE) the dispatcher is enabled to make a decision how to proceed with switching operation in order to restore the services from substation to customers that are not in the fault area and to redistribute the load of the customers of the area where a fault occurred to the neighbouring feeders.

Wang C. W., 2004 [6] Considering the features of spatial data structure in mid-voltage distribution network, the GIS spatial database and planning model suitable to distribution network planning are designed. On this basis and according to the property that the distribution lines are arranged along the streets, the tine structure can be represented by length-varying character chromosome encoding strategy and the preliminary network is formed by the shortest path method. Then, the preliminary network is optimized by genetic tabu hybrid algorithm. In the routing process, different methods are designed adapt to several familiar connection modes such as radial, multisectioned and multilinked, and switching station network. By means of the analysis on actual calculation example, a practical method for distribution network planning is discovered in which the spatial GIS is used for platform, the distribution network planning is tightly correlated with geographical environment and the searching process is guided by optimization algorithms.

Igbokwe, 2005 [7] This paper presents the use of Geographic Information System (GIS) in management of Electricity Distribution Facilities. With inherent limitations faced by traditional system of keeping and managing information, an automated system is developed for National Electric Power Authority (NEPA), Onitsha District in Onitsha-North L.G.A., Anambra State of Nigeria. The administrative\street and electricity distribution network maps were collected from relevant agencies. Electricity distribution facilities spatial database was designed and created using relational database model approach. The paper maps were converted to digital form, through scanning. The raster images were sent to AutoCAD Map R2 environment for geo-referencing and on-screen vectorization. The drawings were edited and exported to ArcView 3.2a environment. The graphics were linked with the created spatial database. The developed system was put to the test by carrying out a number of GIS operation and analysis. Results obtained were displayed in graphics and tables. It was ascertained from the results that GIS is a competent and effective tool for managing electricity distribution network. In this context, conclusions and some useful recommendations were proffered - Spatial and attribute data of electricity distribution network of Onitsha-North Local Government Area, which are presently acquired, processed, managed, stored and presented in analogue form, can be digitalized. Digital system provides timely, accurate, and easier way of acquiring information, which are very vital in taken prompt and accurate decisions necessary in the economic development of any enterprise. [10]Ayeni et al (2003) noted that Geospatial Information (GI) is very essential to economic planning and national development. This is buttressed further by [11]Alamu and Ejiobih (2002), when they concluded that a well maintained utility information infrastructure gives up-to-date information on what is where, the state of it, the reaction other actions on it would cause, how it can be harnessed for optimum use of the people and economy.

Xian-Qi L, 2007 [8] In this paper, geographic information system (GIS) is applied to perform distribution load transfer operation. It's important and significant to perform load transfer for improving the service reliability of distribution network and decreasing outage loss. However, distribution load transfer operation was mostly completed by manual work and experience in the past. Several analysis program modules, such as network analysis and connectivity analysis, are adopt to deal with outage of distribution network on the basis of distribution GIS. The power flow is stored in the database as the attributes of line switches for load transfer analysis. When a system outage such as fault and overload occurs, the load transfer is then executed to find the switches to be operated by the reactive Tabu Search (RTS) method while subjected to the system operation rules. By the proposed method, using the program modules, the network topology can be updated according to switches status. Since all the system facilities are stored in the GIS database according to the actual spatial coordinates, it provides practical information for the system operators and crews to allocate and operate switches easily. Finally load transfer scheme will be given including switches operation and theirs sequence. To demonstrate the effectiveness of the integrated GIS system with application programs using reactive

Tabu search for distribution operation, an urban distribution system is selected for a case study.

Rao, 2008 [9] Geo-spatial information system (GIS) is a powerful tool to Visualize distribution network as it exists on ground. GIS based electrical distribution network analysis amp; design tools enables the planning engineer to visualize the areas of low voltages and high losses; reconfigure network for reduction of losses in planning mode, design of distribution network to extend supply to new customers and siting of new substations to meet load growth etc. This paper describes the experiences in the development of GIS, in absence of network paper map and asset database and usage GIS based tools for analysis, and design of distribution network for the benefit of the utility as well as its customers

Ami, 2008 [10] Experiments are not only the teaching means to improve students practical ability, but also the source to engage them in doing scientific research. Therefore, this paper constructs an authentic vehicle monitoring and dispatching experimental system for logistics distribution with the integrated information technology. The system consists of two parts, one is vehicle terminal system which transmits the information about vehicles and goods to monitoring center system for formulating policy to make plans; and another is monitoring center system, which not only monitors the vehicles status but also identifies distribution routes and dispatching plan by GIS and optimization technique. Eventually, this paper proposes a flexible modularized application system for teaching and scientific research.

Shi, 2008 [11] To find the best repairing path at the shortest time is important for distribution network GIS (geography information system) faults to recovery quickly. After analyzing the existing methods which are usually based on the quantity of nodes, and the time complexities keep in the level of O (n*n), this paper designs an improved Diffluence algorithm whose time complexity is O (m) (m is the number of edges of the shortest path). The efficiency to calculate the best path is improved. Then a mathematical model in distribution network GIS best repairing path that is based on the improved diffluence algorithm is proposed. The paper describes the structure of similar across link list which is used to store network topology when the road condition is considered, and deals with some key algorithms. At last, an instance of distribution network GIS best repairing path considering road condition proves that the efficiency of the improved diffluence algorithm is high.

Li, 2008 [12] Data exported from distribution GIS has become a challenge to distribution system planning and evaluation for its huge consumption of running time to finish a calculation program. In order to solve this problem, this paper proposes simplification method to reduce scale of GIS exported data. In this approach, a typical distribution network can be described by four data structure models, which are original model, whole model, primary feeder model and skeleton model. The data scale of these four models is descending respectively. Further, the simplification

methods for each model are also discussed. The practical data simplification of part of distribution network in Beijing, China has shown that the proposed method can reduce the amount of data significantly. At the same time, simplified data is very close to the original ones. The proposed simplification method and its distribution model of four levels have been successfully implemented in a software system in Beijing Electric Power Company.

Wang S.-Y. W.-M., 2008 [13] Combining the daily operations of the utilities, the latest computer technology and the professional technology of distribution network planning, a practical GIS (geographical information system) based computer decision-making support system with eight sub systems for urban power distribution network planning is introduced. The models and functions of the system are described. This system has been successfully applied in some real urban power networks. The results show that it cannot only can optimize the planning results of urban power distribution network considering many complicated factors, but also reduce the work of computation, analysis and graphic drawing.

Boliang, 2009 [14] In this paper the differential evolution (DE) algorithm is used to solve the substation location optimization problem for a distribution network. To improve the capability of the DE algorithm, the dynamic parameter adjustment strategy is used to guarantee the multiplicity of colony in the initial computation period and enhance the optimization speed of the algorithm in the later period. Using the knowledge of the geographic information system, the graph of possible area of substation location is encoded and stored in data form, the suitable location area is selected on the comparison of network topologies of optional location areas and geographic information. Through the simulation and analysis of a practical example the idea of combining the DE algorithm with graphical display based on GIS database has been successfully employed in distribution network planning.

In this paper a differential evolution algorithm taking into consideration the impact of geographical information factors is adopted for substation planning. Through calculating and analyzing the results of two practical planning zones, and when compared with the PSO, the following points can be concluded: 1) The differential evolution algorithm with considering geographical information factors is more helpful for power planning personnel to site substations. Moreover, the computational result is more suitable for practical use. 2) Due to the peculiar searching mechanism, differential evolution algorithm has better ability of entity optimization on substation location and sizing, despite of being slower in overall speed of convergence when compared with PSO algorithm.

Wang, 2009 [15] The computer-supported decision-making system has become an essential tool for the sustainable growth and expansion planning of modern urban power distribution network. Current packages with planning functions are

independent packages, which are limited in the academic research. Presently, in Shanghai Municipal Electric Power Company and its subordinate units, a geographic information system(GIS)-based production management system(PMS) has been applied successfully as the working platform in most departments, which makes the further research on the computer-aided decision-making system possible and feasible. Taking the PMS as the graphics supporting platform, this paper studies and develops a practical GIS-based decision-making support system for urban distribution network expansion planning, which establishes a primary foundation for information-based planning, daily-frequent planning and elaborate planning. Firstly, the physical structure of the system is designed with a four-layer hierarchical architecture, including the data layer, platform layer, application layer and performance layer, which is suitable for object-oriented development to ensure the security and stability of the system. Secondly, to satisfy the requirements of distribution expansion planning, the main functions of the system are divided into seven modules according to the planning process abstracted in the computer, including the module of current situation analysis, load forecasting, substation locating and sizing, network planning, cable channel planning, economic evaluation of planning and so on. There is at least one or one set of practical mathematical models and methods for planning adopted in each module to ensure the accuracy and reasonableness of the final planning results. Finally, an actual planning of Shanghai, China is accomplished with the expansion planning system. The practical application achievements show that the system can not only optimize the expansion planning results of - urban power distribution network, but also reduce the workload of computation, analysis and graphics drawing dramatically.

Feng, 2009 [16] Geographic Information Systems (GIS) are designed to support the management, manipulation, analysis, and modeling of spatial data. At present, GIS has been extensively used in the energy management system and distribution management system. It provides visualized platform to electrical distribution system analysis, design and operation, that is, AM/FM/GIS. Once AM/FM/GIS integrate with SCADA, the real time operational data can be displayed in the platform. Distribution network reconfiguration is an important measure for network optimization and loss reduction. Tabu search is a new heuristic searching algorithm which is suitable for solving complex and multiple objectives optimization problem. In this paper, the algorithms used in solving distribution network reconfiguration are introduced. Based on GIS, the distribution network is modeled as geometric network. All electrical distribution system facilities including the network buses, branches, switches and transformers were abstracted into edges and nodes. An improved approach based on TS is presented to match the model. At last, the presented method is validated by typical testing system and some city district electrical distribution system.

The paper proposed a TS method to solve the distribution network reconfiguration based on GIS platform considering the new model of distribution network in geometric network. The approach is successfully demonstrated with some city

district electrical distribution system. In order to solve the reconfiguration problem based on geometric network, many algorithms will be tested to find the better one in the further research.

Triplett, 2010 [17] Distribution system losses are a reality due to the physics associated with various system components that make up any power system. Techniques for analyzing losses are not new but have primarily focused on evaluating system losses during certain peak demand periods due to limitations on available data. Such traditional analyses estimate energy losses using industry accepted approaches that rely heavily on assumptions and that focus only on peak and average demands on major system components. Another potential shortcoming of a traditional loss analysis is the level of system detail evaluated. A gross analysis in terms of system components such as substation power transformers, distribution lines, distribution transformers, secondary conductors, etc. is typical. The disadvantage is that the relative contribution of various system components to the overall system losses may not be defined to the level required to truly evaluate mitigation techniques, especially when time periods other than peak demand times are being evaluated. Given the limitations of traditional loss evaluations, this paper will explore enhanced loss evaluation techniques utilizing interval load data collected from a deployed Advanced Metering Infrastructure (AMI) system and detailed system data from an available Geographic Information System (GIS). The test case system used to present this approach was a distribution cooperative with these systems presently in place.

Otsego Electric Cooperative has been successfully calculating monthly losses using data from their AMI system for almost a year. This has resulted in a more accurate representation of total system losses by substation area. The detailed hourly loss calculation methodology presented in this paper that utilizes data from a deployed AMI and GIS system was successfully applied to a test case area on the Otsego Electric Cooperative system. This evaluation has resulted in much greater insight into the magnitude of losses by system component at various loading levels. Given all of the challenges associated with collecting hourly interval load data for a large number of meters, collection of this data over an extended period of time may not be practical or even particularly useful. Rather, collecting load data for select system states of interest, from light loading to peak loading conditions, and applying the hourly loss calculation method presented in this paper may be a better approach.

Sinha, 2010 [18] Till now, power distribution utilities in India have been using GIS technology for electrical consumer indexing and asset mapping function generally as a stand-alone application. However, due to the recent impetus on distribution reforms with central funding, many utilities have come to realize the importance of integrating the GIS components with core business processes like new connection management, meter data acquisition, billing, collection and customer care, network analysis and energy audit. This paper discusses the approach being adopted by state distribution utilities and challenges faced in the integration of core business functions

on a common framework using GIS, with the purpose of better customer and assets management, operations management and controlling ATC losses. The state utilities now prefer to have a GIS middleware integration platform using a parameterized business rules engine and a service oriented architecture (SOA).

Power Distribution system constitutes the link between electricity utilities and consumers. This system, therefore represents the face of the utility. To meet the growing and changing system load demands, proper power distribution planning needs to be done by the utilities. Use of Geographical Information System (GIS) will facilitate proper planning and analysis for power distribution networks.

3. Description of Broad Area/Topic

Most advanced Power Utilities have made major gains in terms of productivity, efficiency, reliability and commercial management through the use of modern technologies. It has been observed that, compared to the situations prevailing abroad, the Indian Power utilities are still lagging behind. Acute need for a consistent and long lasting solution aimed at improving and strengthening of the Power Distribution Network with minimum Losses in the long run through integrated planning for Power Distribution System has been felt for a long time now. Geographical Information System (GIS) technology plays an important role in mapping the HT/ LT consumers and electrical network assets, on a geographical base map, to help define the consumer's electrical connectivity. The aim of the research would be to integrate data using GIS to plan and analyze a distribution network for system optimization

4. Objectives of the study

The main objectives of my research would be to:

Use GIS for planning and analysis of Power Distribution System through:

i) Network Creation – Geographic representation
ii) System Analysis
iii) System Optimisation

5. Methodology to be adopted

5.1 Data Collection

Data will be collected from Primary as well as secondary sources related to a Distribution Network

The following data would be required

i) Category wise number of consumer and connected load including Bulk Consumers' details
ii) Demand Data
iii) Network Data (Geographical maps)

This data will be collected from a utility. Once the Electrical database of the network is imported into GIS, the resulting network model will be analyzed for system optimization for minimizing losses.

5.2 Sample: The sample will be for the year 2002-2009 for a particular utility

5.3 Research Technique: System will be tested on GIS/MATLAB

6. Expected Outcome of Research

The utility industry has undergone significant changes in the past few years. Deregulation has increased competition, and utilities are becoming more market-driven than ever before. The utilities are looking at how GIS can help them reduce costs, expand capabilities, improve customer service and become more marketable

The distribution utilities are facing various challenges like,

- Elimination of human intervention in data creation of consumer, metering and billing
- Updating of dynamic data of consumers and assets uniformly throughout utility
- Development of suitable MIS for middle & top management
- Proper planning, energy audit & accounting
- Meet regulatory & statutory requirements
- Provide consumer satisfaction

Hence in present scenario, it is highly necessary to monitor the distribution on a real time basis. Network Mapping and analysis will prove to be a tool of immense benefit to the Power Distribution System Utility in improving the operating efficiency and consequently customer satisfaction.

The expected outcome of the study would be beneficial for Distribution utilities.

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